

THE LONGITUDINAL STRENGTH ANALYSIS OF AQUACULTURE FLOATING STRUCTURE IN INDONESIA SEA WATER

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ABSTRACT

The innovation of aquaculture floating structure is developing in the country, where the maritime sector is the potential aspect to improve the country revenue. The design of the aquaculture facility needs to be carried out an analysis about the construction profile so that the floating structure can be able to withstand the wave load applied along the body. This research is done by using numerical methods. The distribution of weight is carried out based on the Cross-Section Area (CSA) graph which the total weight is equal to the light weight of floating structures. The shear stress and bending moment are calculated at the section of mid-ship and it is taken two cross sections which the first one has a full plate in the main deck and the second one have a hatch. The section modulus should be appropriately calculated in the two cross sections. In order to obtain the result of wave load in the irregular wave, the sea states are varied in 3 to 6 to obtain the magnitude of shear stress and bending moment. The output of this research is to know that there are different criteria of stress occurred between two cross sections analyzed. In other hand, the variation of sea state will show the extent to which the cross section is able to withstand the wave load.

KEYWORDS: Wave Load, Shear Force, Bending Moment, Cross Section Area & Stress

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INTRODUCTION

Nowadays, the development of maritime facilities gets up some of innovations associated with the development of science and technology. One of the innovations is an aquaculture floating structure used to be as a place of fish farming in the offshore. The Ministry of Maritime Affairs and Fisheries, ministry working for the improvement of the fishery sector, is building and revitalizing some of the aquaculture facilities including existing ones. This effort aims to improve and increase the production of fish farming in order to be a self-supporting country in food. Nowadays, the development of maritime facilities gets up some of innovations associated with the development of science and technology. One of the innovations is an aquaculture floating structure used to be as a place of fish farming in the offshore. The Ministry of Maritime Affairs and Fisheries, ministry working for the improvement of the fishery sector, is building and revitalizing some of the aquaculture facilities including existing ones. This effort aims to improve and increase the production of fish farming in order to be a self-supporting country in food.

The problem of aquaculture floating structure is about the longitudinal strength and mooring tension and which is equally problematic for other floating structures. Because of the large of hatch, the longitudinal strength will be reduced, so that it will be worried that the deck structure is broken.



Figure 1: The Aquaculture Floating Structure in Norwegian

LITERATURE REVIEW

The vertical wave-induced in a ship is carried out by using the strip method which the environmental condition is in the shallow water. The wave load is derived from the analytical method by a modified linear frequency [4]. The fluid flow acting along a floating structure will produce the drag force. Because the flow speed is small, it is usually neglected [5]. The non-linear wave load analysis is done by using a Rankine Panel Method together with numerical method in order to simplify the mathematical equation. Because the time domain is in the long term, the wave load used is the design wave amplitude for the non-linear analysis. When a ship in sagging and hogging conditions, the maximum bending moment is created as the function of wave frequency. The final result obtained is that the sagging of green water does more effect than the hogging of one [1].

The wave load can be analyzed through analytical, numerical, and experimental approaches. Numerically, CFD and strip method is usually carried out to calculate the wave load. For the needs of the industry, the prediction method is a solution to produce the wave load by entering the variable of principal dimensions and environmental conditions [7].

An analytical method used to determine the longitudinal strength of ship is applied for the damage case. The important consideration is the residual stress that had still been owned by the ship structure. The structure will reduce because a part of section modulus, for example, in mid-ship, is caused by the collision or any accidents [6]. The smaller model of longitudinal web stiffeners is ever carried out an analysis about the shear strength. The Semi-Analytical Finite Strip Method (SAFSM) is used for the analyses. The shear buckling strength is the output of this project [3]. For the industry consumption, the analytical method is simplified to obtain the longitudinal strength of large sailing yachts. There are many simulations using Finite Element (FE) to calculate the longitudinal strength with the parameter of stress [2].

RESEARCH METHODS

Still Water Loads

Hydrostatics, which are affected by the weight and buoyancy distributions, are used as input data to calculate the shear force and bending moment in still water.

$$V_x = \int_0^x W dx = \int_0^x w dx - \int_0^x b dx \quad (1)$$

$$M_x = \int_0^x W dx = \int_0^x w dx - \int_0^x b dx \quad (2)$$

The shear force (V_x) is determined by the integration of weight (w) and buoyancy (b) which can be shown in Equation 1. On the other hand, the bending moment (M) is as a function of the moment of weight (w) and the moment of buoyancy (b) which can be shown in Equation 2. The first step in the determination of the still water bending moment is to balance the ship for a certain weight distribution, so that the total weight and the longitudinal center of gravity of the ship coincide with the displacement and the longitudinal center of buoyancy. This step is done by trial and error in order to obtain the displacement is zero.

Bending Moment in Regular Wave

For study of a longitudinal strength, it is more desirable to be known the bending moment in any point along the length. The force acting on a ship can be calculated by using the strip method. To be able to calculate the bending moment in any station along the length, the equation of motion should be solved in order to obtain the amplitude of the bending moment. Because of the regular ship motion, the pattern of the bending moment graph does always follow the sinusoidal graph. For any instant of time, the bending moment can be found by calculating the longitudinal distribution of the total force. The bending moment can be obtained by integration of the shear force at any station. While the shear force can be calculated by integration of the loading over the ship length. The loads applied in a long ship consisted of: 1) The distribution of weight and buoyancy in calm water; 2) The loading affected by the change of the buoyancy, because the wave pattern acting in a ship which can be formulated in Equation 3; 3) The loading due to the Smith Effect representing the pressure gradient in the wave which can be shown in Equation 4; 4) The loading caused by the relative water velocity of wave and ship motion. From the Equation 5, the first term is influenced by the free surface while the second term is affected by the development of the potential theory; 5) The loading due to the inertial force, added mass, and inertial effect of the water flow in waves which can be shown in Equation 6.

$$\frac{df_b}{dx} = -c_n z_r = -\rho g B_n (z - \xi \theta - \xi) \quad (3)$$

$$\frac{df_c}{dx} = -c_n \xi (1 - e^{-kz}) = -\rho g B_n \xi (1 - e^{-kz}) \quad (4)$$

$$\frac{df_d}{dx} = -b_n w_r + u \frac{da_n}{d\xi} w_r \quad (5)$$

$$\frac{df_e}{dx} = -m_n \ddot{z}_n - a_n \dot{w}_r \quad (6)$$

Equation 3 to 6 are only the loading in each section so that the integration of those equation will produce the loading along the ship. The dynamic shear force $f(x)$ is obtained by the total of all loadings which can be written in Equation 7. Similarly, the dynamics bending moment can be written as Equation 8.

$$f(x) = \sum_{i=a}^e \frac{df_i}{dx} \quad (7)$$

$$m(x) = \int_0^x f(x) dx = m_0 \cos(\omega_e t + \beta) \quad (8)$$

Calculation for the Inertia Moment, Section Modulus, and Stress

After the shear stress and bending moment acting along the floating structure had been obtained, the next step is to calculate the stress occurred in each section of the floating structure. A floating structure has to be able to safely withstand the shear force and bending moment. The condition avoided is the stress occurred is more than the stress allowance and the construction is buckling. The formula to calculate the stress can be shown in Equation 9. The stress σ can be obtained from the dividing of the dynamics bending moment m_0 and inertia moment in neutral axis I_{NA} . The cross-section area in the mid-ship should be symmetrical between Portside and starboard sides. The inertia moment in neutral axis can be calculated by using Equation 10.

$$\sigma = \frac{m_0}{I_{NA}} \quad (7)$$

$$I_{NA} = \sum I_0 + \sum a_i^2 A_i - a_{NA}^2 \sum A_i \quad (8)$$

RESULT AND ANALYSIS

Using simple calculation, the distributions of weight, buoyancy, superposition, shear force, and bending moment can be shown in Figure 2. The maximum bending moment in the midship is about 35 ton m where the maximum stress is occurred. To determine the section modulus in two cross sections, Figure 3 shows two cross sections in the full deck of main deck and the main deck with a hatch.

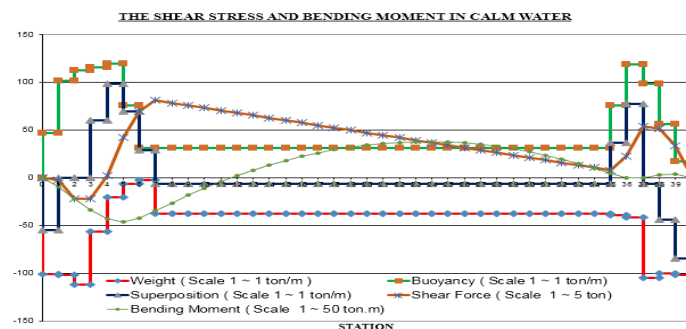


Figure 2: The Distribution of Weight, Buoyancy, Superposition, Shear Force, and Bending Moment in Calm Water

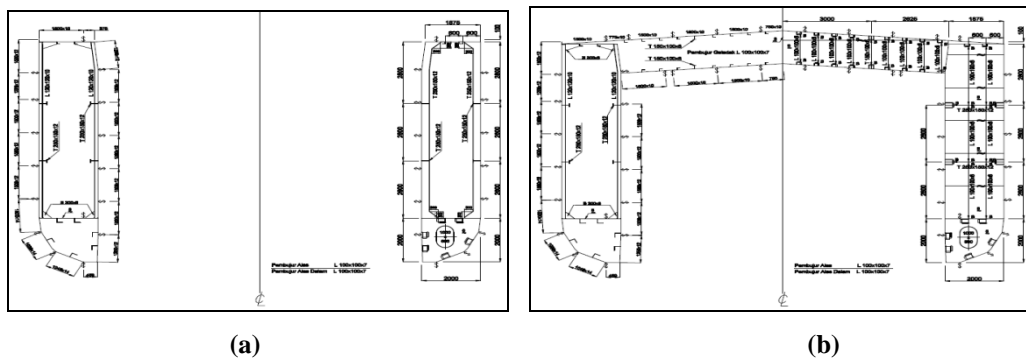


Figure 3: Two Cross Sections in The Midship Area Which are
a) Main Deck with a Hatch and b) Main Deck with Full Plate

The shear force and bending moment are calculated by using strip method which this method is carried out by

dividing the floating structure in the several cross-sections. In this model, the cross-sections are 20 areas started from after peak to fore peak of the aquaculture floating structure. The body plan of this model can be shown in Figure 4.

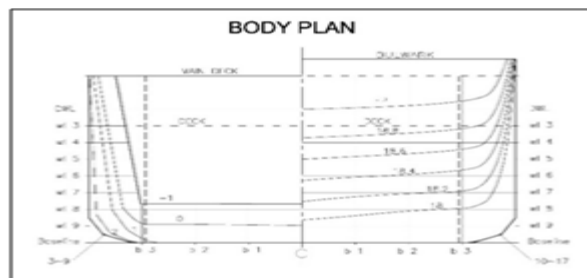


Figure 4: The Body Plan of Aquaculture Floating Structure

Table 1 shows that the stresses occur in two cross sections is different, because the bending moment and inertia modulus are not same. For main deck with a full plate, the stress occurs is 52.3 MPa which this stress is still less than the stress allowance. The stress allowance for steel is 225 MPa. Similarly, for main deck with a hatch, the stress occurs is 86.9 MPa which this one is still less than the stress allowance.

Table 1: The Stress Occurred in the Two Cross Section

No	Area	Inertia Modulus (m ³)	Bending Moment (ton m)	Stress (MPa)
1.	Main Deck with Full Plate	6.5×10^{-3}	34.3	52.3
2.	Main Deck with a Hatch	3.7×10^{-3}	32.1	86.9

For the environmental condition, the sea water does impossible occur in regular wave, but it is always in irregular wave. In order to determine the irregular wave, the term of sea state can be used as the tier of significant wave height. Table 2 shows the tier of sea state as a function of the significant wave height.

Table 2: The Sea State Based on the Significant Wave Height

No	Sea State	Hs (m)
1.	3	1.0 – 1.5
2.	4	1.5 – 2.0
3.	5	2.0 – 3.5
4.	6	3.5 – 4.5

The Joint North Sea Wave Observation (JONSWAP) spectrum, the probabilistic method for the wave spectrum, is used to the shear force and bending moment in the irregular wave. This spectrum will be multiplied by the Response Amplitude Operator (RAO) of shear force and bending moment in regular waves. Figure 5 shows the wave spectrum with variation in sea state by using JONSWAP spectrum.

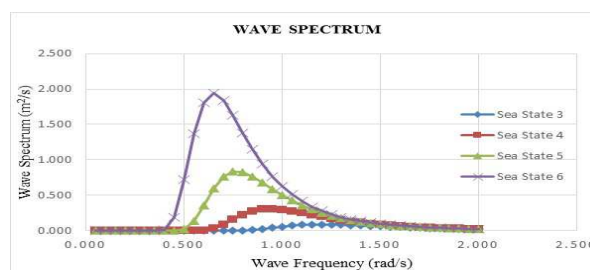


Figure 5: The JONSWAP Spectrum

Wave spectrum $S_{\zeta}(\omega_w)$ is a function of wave frequency ω_w in the various of sea state. The largest of wave spectrum is in the sea state 6 which it means the largest of significant wave height. In the worst case, the heading angle is taken at the 0 or 180 degrees. Because the aquaculture floating structure does not move, the wave encountered is equal to the wave frequency. Before the wave spectrum is multiplied by the RAO, the wave spectrum should be changed as a function of the wave encountered.

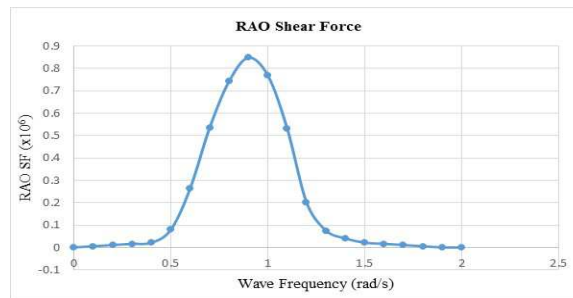


Figure 6: The RAO of Shear Force

The RAO of shear force and bending moment needs to be calculated which it describes the wave load in the regular wave. Figures 6 and 7 explain the RAO of shear force and bending moment, respectively, for the heading angle 0 or 180 degrees. From the RAO of shear force and bending moment, the maximum value is in the wave frequency 1.1 rad/s which it means that at the certain wavelength, the response of wave load is occurred in the maximum condition. When the wavelength is very long and very short, the response of shear force and bending moment is in the minimum condition. The pattern of wave load can change at the irregular wave. Figures 8 and 9 describe the response spectrum of shear force and bending moment in the various sea state.

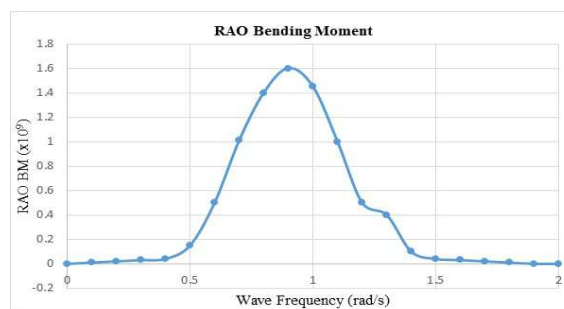


Figure 7: The RAO of Bending Moment

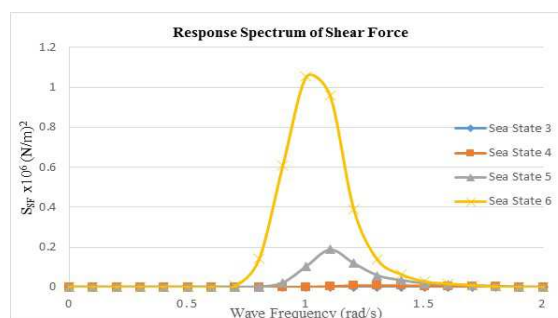


Figure 8: The Response Spectrum of Shear Force

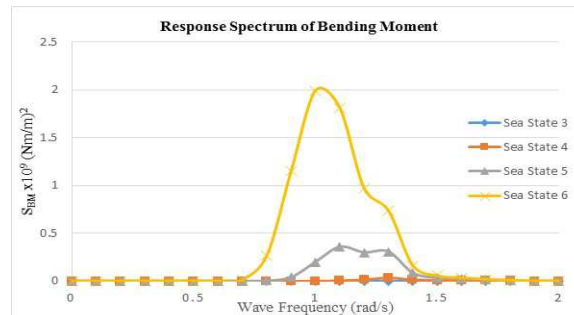


Figure 9: The Response Spectrum of Bending Moment

Table 3 explains the significant bending moment and stress occurred in various of sea state. The significant bending moment can be calculated based on the integration of response spectrum of bending moment along the wave frequency. Then, the area below the graph of response spectrum should be rooted and multiplied by two, so that the significant of bending moment can be obtained.

Table 3: The Significant Bending Moment BM_s and Stress Occurred in Various of Sea State at the Main Deck with Full Plate σ_1 and with a Hatch σ_2

No	Sea State	BM_s (ton m)	σ_1 (MPa)	σ_2 (MPa)
1.	3	44.9	69.1	121.4
2.	4	58.1	89.9	157.2
3.	5	71.1	109.4	192.4
4.	6	85.8	132.1	232.1

CONCLUSIONS

- The longitudinal strength of the aquaculture floating structure is still able to withstand the shear force and bending moment in the calm water condition. The maximum stress occurred in the main deck with full plate is 52.3 MPa and the main deck with a hatch is 86.9 MPa.
- In the irregular wave, the significant bending moment is used to calculate the stress occurred in the cross-section area. The maximum stresses in the main deck with full plate are 69.1, 89.9, 109.4, and 132.1 MPa for sea state 3, 4, 5, and 6 respectively. It means that the longitudinal strength of the aquaculture floating structure is still able to withstand the wave load in several sea states.
- The maximum stresses in the main deck with a hatch are 121.4, 157.2, 192.4, and 232.1 MPa for sea state 3, 4, 5, and 6 respectively. From this result, the stress occurred in sea state 6 is not able to withstand the wave load so that the floating structure is worried to break.

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